

SECTION 34 21 21

TRANSFORMER-RECTIFIER UNITS

PART 1 – GENERAL

1.01 SECTION INCLUDES

- A. Rectifier transformers
- B. Traction Rectifiers

1.02 MEASUREMENT AND PAYMENT

- A. Measurement: Transformer-rectifier units will be measured for payment as a lump sum unit acceptably installed and tested for compliance.
- B. Payment: Transformer-rectifier units will be paid for at the Contract lump sum price for Transformer-rectifier units or as part of the lump sum price for Traction Power Substations, by location, as determined by the lump sum measurement specified above, as indicated in the Bid Schedule of the Bid Form.

1.03 REFERENCES

- A. American National Standards Institute (ANSI)
 - 1. ANSI C34.2 Practices and Requirements for Semiconductor Power Rectifiers
 - 2. ANSI C37.20.1 Metal-Enclosed Low Voltage Power Circuit Breaker Switchgear
 - 3. ANSI C37.20.2 Metal-Clad and Station-Type Cubicle Switchgear (above 1000V)
 - 4. ANSI C37.41 Design Tests for High Voltage Fuses, Distribution Enclosed Single Pole Air Switches, Fuse Disconnecting Switches and Accessories
 - 5. ANSI C37.45 Specifications for Distribution Enclosed Single-Pole Air Switches
 - 6. ANSI C57.12.00 Standard General Requirements for Liquid-Immersed Distribution Power and Regulating Transformers
 - 7. ANSI C57.12.01 General Requirements for Dry-Type Distribution and Power Transformers
 - 8. ANSI C57.12.10 Transformers – 230 kV and Below 833/958 Through 8,333/10,417 kVA, Single-Phase, and 750/862 Through 60,000/80,000/100,000 kVA, Three-Phase Without Load Tap Changing; and 3,750/4,687 Through 60,000/80,000/100,000 kVA with Load Tap Changing – Safety Requirements

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9. ANSI C57.12.51 Requirements of Ventilated Dry-Type Power Transformers, 501 kVA and Larger, Three-Phase, with High-Voltage 601 to 34500 Volts, Low Voltage 208Y/120 to 4160 Volts
 10. ANSI C57.12.56 Test Procedures for Thermal Evaluation of Insulation Systems for Ventilated Dry-Type Power and Distribution Transformers
 11. ANSI C57.12.70 Terminal Markings and Connections for Distribution and Power Transformers
 12. ANSI C57.12.91 Test Code for Dry-Type Distribution and Power Transformers
 13. ANSI C57.18 Pool-Cathode Mercury Arc Rectifier Transformers
- B. Electronic Industries Association (EIA)
1. EIA RS-282 Standards for Silicon Rectifier Diodes and Stacks
- C. National Electrical Manufacturer's Association (NEMA)
1. NEMA RI-9 Rectifier Transformer
 2. NEMA TR-1 Transformers, Regulators, and Reactors

1.04 SUPPLIER QUALIFICATIONS

- A. The manufacturer of the rectifier transformers must have a minimum of 5 years manufacturing experience with the cast resin technology applied on power transformer coils.
- B. The Engineer responsible for the design of the rectifier transformers must have a minimum of 5 years of project-proven experience in the design of 3-winding rectifier transformers.
- C. Transformers and rectifiers shall be proven standard products, or equivalent to the standard products of manufacturers engaged in the production of such equipment for at least the past 5 years.

1.05 SUBMITTALS

- A. General: Refer to Section 01 33 00 - Submittal Procedures, and Section 01 33 23 - Shop Drawings, Product Data, and Samples for submittal requirements and procedures.
- B. Product Data: Submit product data to include the following:
 1. Physical arrangement and assembly of parts
 2. Wiring connections
 3. Schematic drawings
 4. Brief description of devices and their functions and special features.

5. Equipment nameplate
 6. Transformer data including rated kVA, frequency, primary and secondary voltages, percent taps, polarity, impedance and certification of transformer performance efficiency at indicated loads, percentage regulation at 100% and 80% power factor, no-load and full-load losses in watts, % impedance at 75°C, hot-spot and average temperature rise above 40°C ambient temperature, sound level in decibels, and standard published data.
- C. Operations and Maintenance Manuals. Submit operation and maintenance manuals complying with the requirements of Section 01 78 23 - Operation and Maintenance Data.
- D. Test Reports. Submit reports of tests performed on the transformer-rectifier units.
- E. Installation Manual. Submit manufacturer's recommended installation procedures for the rectifier-transformers.

PART 2 - PRODUCTS

2.01 GENERAL

- A. Each unit shall consist of a rectifier transformer and a traction rectifier with all necessary hardware, wiring, and devices as indicated, and as required for a complete and operating installation.
- B. The rectifier transformer will receive 34.5 kV, 3-phase, 60 Hz, 3-wire power from a 34.5 kV switchgear and shall transform the high voltage to a low ac voltage rated as required by the traction rectifier.
- C. The traction rectifier will receive the low voltage ac power from the secondary winding of the rectifier transformer and convert the ac voltage to nominal 1000 V dc. Output power of the rectifier supplies the dc switchgear.
- D. The rectifier transformer and traction rectifier shall be designed for interconnection by ac busways as indicated. Connections between the rectifier and the dc switchgear shall be by dc cables or bus as indicated.
- E. The transformer/rectifier units shall be designed and fabricated in accordance with the applicable ANSI and NEMA standards.
- F. In lieu of the warranty period duration required in the General Conditions, the warranty period for the rectifier transformers shall be five years.

2.02 OVERLOAD REQUIREMENTS

- A. The transformer-rectifier unit shall be rated for extra heavy duty traction load. The unit shall be able to operate at the following overload cycle, beginning from operation at nominal load and stabilized temperature:
 1. 150 percent of rated current for 2 hours, with superimposed 5 periods of 1 minute duration at 300 percent of rated current each, equally spaced throughout the 2-hour period, and

2. 450 percent of rated current for 15 seconds at the end of the two hour period.
- B. The transformer-rectifier unit shall withstand two overload periods as specified above on a daily basis, spaced 8 hours apart, each preceded and followed by the continuous 100 percent load level.
- C. The transformer-rectifier units shall be designed to meet the above daily duty cycle without damage to any parts or the insulation for a period of 25 years.
- D. Current unbalance caused by loss of one diode per phase shall be taken into consideration in the design, and shall not reduce the specified overload capability of the rectifier.

2.03 RATINGS

- A. Unit Capacity
 1. The KW rating of the transformer-rectifier units shall be as indicated. The units shall be designed to deliver the rated KW output at rated terminal voltage.
 2. The units shall withstand continuous operation at 110 percent rated voltage without exceeding the equipment temperature limitations.
- B. Efficiency: The overall efficiency of the transformer-rectifier units shall be greater than 97.5 percent at its continuous rating. No-load core losses shall not exceed 0.15% of the rated unit capacity.
- C. Power Factor: The displacement power factor of the transformer-rectifier units shall be 0.95 or greater from 25 percent to full load with rated ac input voltage.
- D. Regulation: The transformer-rectifier units' initial regulation shall be 6 percent. The regulation shall be linear from light transition (one percent) load to at least 300 percent of full load. Manufacturing tolerance shall not exceed ten percent of the specified regulation value. The voltage at the rectifier output at no-load shall not exceed 1200 V dc at rated primary voltage of 34.5 kV. The light transition load voltage shall be in the 1,055 to 1,060 volts dc range.
- E. Short-Circuit
 1. Each transformer shall be designed to withstand a full short-circuit at the low-voltage terminals at rated voltage on the high-voltage terminals for one second, in accordance with ANSI C57.12.00 and C57.12.01.
 2. All parts of the rectifier unit, including the terminal connections and buswork, shall be designed to withstand a bolted fault on the dc positive bus, without damage, for the time period required for the backup protection to operate and open the ac circuit breaker.
 3. The transformer shall be designed to withstand the short-circuit power available from the 34.5 kV subtransmission lines at the switching stations which is expected to be up to 500 MVA.

4. The secondary windings of the rectifier transformer shall be coupled magnetically, so that at a given fault level of 500 MVA at 34.5 kV, the sustained short circuit current on the rectifier bus for a bolted fault does not exceed nine times the full load current.

F. Minimum Ratings: The rectifier transformers shall have the following minimum ratings:

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|----|---|-------------|
| 1. | Cooling Class | AA |
| 2. | Primary Winding Nominal Voltage | 34.5 kV |
| 3. | Secondary Winding Nominal Voltage | as required |
| 4. | Frequency | 60 Hz |
| 5. | No. of Phases | 3 |
| 6. | Winding Temperature Rise above 50°C
ambient after stabilized continuous
operation at 100 percent load | 55°C |
| 7. | Hottest-Spot Temperature Rise above 50°C
ambient after stabilized continuous
operation at 100 percent load | 65° C |
| 8. | High-voltage Winding Basic Insulation
Level (BIL) for operation on a 34.5 kV
line-to-line, effectively grounded
neutral system | 170 kV |
| 9. | Low-Voltage Winding Basic Insulation
Level (BIL) with a voltage rating
suitable for supplying the rectifiers | 45 kV |

G. Voltage Transients

1. A plan of the design techniques, construction methods, and equipment employed to protect against transient surge voltages shall be submitted for approval.
2. If fuses are used in surge suppression networks, they shall be monitored by visual indicators, and shall be equipped with devices capable of being monitored by a local annunciator.
3. A surge protection network at the input terminals shall protect each rectifier unit from damage due to switching voltage transients up to 2.5 times normal voltages in the 34.5 kV ac system. Failure of the surge protection network shall be annunciated as indicated.
4. A static voltage surge suppressor rated to withstand expected voltage transients, shall protect each rectifier from lightning surges transmitted along dc contact rails, and from voltage transients on the dc system due to breaker switching. A counter shall be provided for the surge suppressor. Failure of the surge suppressor shall be annunciated.

5. The surge suppressor shall absorb surge energy of 50 kilojoules minimum with bus potential below 2600 volts at instantaneous current of 4000 amperes.
6. The peak value of contact rail transient voltages are expected to be 3000 volts for 8 milliseconds or 6000 volts for 50 microseconds with rise time of 1.2 microseconds.

H. Noise Levels

1. Equipment design, enclosures with acoustic mitigation capability, and other measures, as appropriate, shall be employed to achieve compliance with the specified audible noise level criteria.
2. The noise level measured at a distance of 15 feet from the rectifier transformer with the transformer operating at 100 percent load, shall not exceed 55 dBA.
3. The noise level measured at a distance of 5 feet from the rectifier with the rectifier operating at 100 percent load, shall not exceed 60 dBA.
4. Submit proof in the form of calculations or empirical data that the rectifier transformer meets the noise level requirements.

2.04 RECTIFIER TRANSFORMERS

A. General

1. The rectifier transformers shall be of the self-cooled outdoor type in accordance with ANSI C57.12.10, C57.12.70, C57.18 and NEMA TR-1. The rectifier transformers shall be cast coil type conforming to the applicable requirements of ANSI C57.12.01, C57.12.51, and C57.12.56.
2. The primary windings shall be delta-connected and rated for 34.5 kV, three phase, 60 Hz.
3. The secondary windings shall be delta/gye for the two six-pulse double-way rectifiers in accordance with ANSI C34.2, circuit number 31. Ratings of the secondary windings shall meet the same performance requirements as the rectifiers.
4. All transformer windings shall be of the wound conductor construction, and the insulation shall be of the cast-coil type, cast under vacuum with epoxy resin.
5. The cast coil type transformer shall be furnished with an outdoor metal enclosure with maximum height of 12 feet. Enclosure shall be constructed of sheet steel, not less than No.11 gauge. Enclosure door shall be hinged type and shall have provision for padlocking. Steel parts of the enclosure shall be hot-dipped galvanized, and after welding and cutting, affected areas shall be spot galvanized with galvanizing primer. Fastening hardware such as nuts, bolts, and washers shall be cadmium plated. Doors shall be provided with interlocks, which upon door opening shall initiate tripping of the lockout relay (device 286). The enclosure shall contain louvers or mesh openings to provide adequate ventilation and air cooling of the components. Ventilation openings shall not be located less than six inches above the floor or where they would allow entry of debris and dirt.

B. Taps and Tap Changers

1. The high-voltage winding shall have four no-load, full capacity taps: two 2.5 percent above, and two 2.5 percent below the rated line-to-line voltage of 34.5 kV.
2. The tap changing shall be by movable links. Tap connections shall be clearly marked so that the tap selected is clearly identifiable. The tap changing links shall be securely bolted in position. The design of links and connectors shall make it impossible to short out sections of windings, or to select taps outside the prescribed range, by incorrectly connecting the links.
3. The tap position indicator shall be visible through a viewing window.

C. Transformer Handling

1. The transformers shall be protected from condensation and the weather, and the shipping containers shall be marked for special handling.
2. Lifting lugs shall be provided to facilitate transformer shipping and installation.

D. Transformer Protection

1. Winding temperature (Device 226WT) gauges shall be provided and mounted for viewing from outside of the transformer enclosure through a viewing window. The temperature gauge shall be provided with two-stage contacts. First stage contacts shall be for annunciation and second stage for breaker tripping.
 - a. The pickup point of each stage shall be adjustable and factory-set so that upon a designated temperature increase the device initiates an alarm.
 - b. Further temperature increase, the device shall initiate the tripping of the station through lockout relay identified as device 286 on the Contract Drawings.

E. Terminations

1. The rectifier transformers shall be designed for high-voltage cable connection and low-voltage throat connection.
 - a. The high-voltage cable connections shall have removable links, which when removed, shall leave gaps wide enough to preclude arcing when performing Hi-Pot tests.
 - b. The low-voltage throat connection to the rectifier shall align, match, connect, and be compatible with the flange and bus bar connections of the ac busway.
2. Cable connectors with NEMA 2-hole shall be provided for the cable size indicated. 34.5 kV power cable terminations shall be by stress cones.

F. Base Construction

1. Base construction shall allow rolling or skidding by pulling along the centerlines perpendicular to each side.
2. Base construction shall secure the core to prevent relative motion of the core and coil during shipment, handling, or seismic shock. Mounting shall meet the BART Seismic Design Criteria requirements and shall be fitted with anti-vibration and acoustic dampers.
3. Base construction shall be provided with structure steel support beams, ready to be mounted on a concrete pad.
4. Jacking facilities shall be provided at each of the four corners of the base.
5. At least two copper ground pads shall be provided.

G. Protective Screen. The top of open transformer coils shall be furnished with non-ferrous screen or mesh to preclude foreign materials from falling between the transformer coils.

2.05 TRACTION RECTIFIERS

A. General

1. Each rectifier section shall be a complete self-contained unit consisting of silicon diodes, protective fuses, cooling system, bus connections, hardware, gaskets, and all other necessary accessories.
2. The rectifier shall be the indoor type, with natural convection-cooling, and shall be designed to operate at 50°C ambient temperature.
3. The rectifier shall consist of two six-pulse, delta-wye, double-way circuits each having six legs of diode devices, per ANSI C34.2 circuit No. 31.
4. An interphase transformer shall be provided between the direct outputs of the six-pulse sections to absorb the instantaneous direct voltage differences. To achieve the lowest practical noise level, the core of the interphase transformers shall be designed to minimize the magnetostriction. Magnetostriction is the phenomenon of elastic deformation that accompanies magnetization. Noise damping treatment may be required in reducing noise level by cancelling some of the frequencies of the transformer noise. The Contractor shall submit calculation that shows the noise level expected for the transformer under full load or maximum excitation meets the specified noise level limits. The calculation shall be signed by a California registered engineer specialized in noise suppression field.
5. Materials shall be chosen to preclude the possibility of corrosive or galvanic action between dissimilar metals. Compatible materials shall be used for diode cases, studs, and heat sinks.
6. The rectifier enclosures shall be designed for high-resistance enclosure ground relaying.

B. Rectifier Enclosures

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1. All panels comprising the rectifier enclosure including doors shall be constructed of sheet steel, not less than No. 11 gauge, and mounted on rigid, self-supporting structural steel framework.
2. Glastic type insulation shall be provided between the rectifier and dc switchgear and between the rectifier and the negative return cabinet.
3. Louvered or mesh openings shall provide ventilation and air cooling of the components by natural convection.
4. Ventilation intake openings shall be located not less than six inches above the floor.
5. Heat transfer surfaces and ducts shall be designed with smooth surfaces that minimize accumulation of dust and other contaminants.
6. Convenient access shall be provided for all normal maintenance and inspection.
7. Each door shall be equipped with
 - a. a mechanical latch to hold the door closed and
 - b. door stops to hold door open for inspection of rectifier components.
8. Openings and mounting holes for front mounted indicating and control devices shall be cut out, drilled, or punched without marring or distorting the exposed finished surfaces of the control cubicles.
9. Diode monitoring lights and fuse indicators shall be visible through windows without opening doors.
10. Separate compartments shall be provided to isolate control and auxiliary circuits and functions from the 1000 V dc buses and diodes.
11. All readings, controls, and observations shall be made without exposure to live parts. Internal lights with an external switch shall be included. Lighting fixtures shall be provided with guards.
12. All components installed in the rectifier shall be capable of withstanding 4600 V dc for one minute, applied between completely assembled rectifier and ground, with control circuits connected and energized or grounded, except that ground connection to the 164A/164G relay shall be disconnected and its contact set in the OPERATE (tripped) condition.
13. The enclosure shall be connected to the high resistance ground relay (Device 164A/164G) in the associated DC switchgear.

C. Diodes

1. Diodes shall be rated and tested in accordance with EIA RS-282. Parallel strings of diodes shall be geometrically similar and as symmetrical as practicable to balance the normal and surge electrical characteristics of each string.

2. In addition to the parallel strings necessary to handle all loads as specified, additional capacity shall be provided so that, with one diode per phase leg out of service, each current path will still handle all specified loads and maximum short circuit current.
3. Each diode shall withstand, at its maximum operating temperature, voltages 2.5 times its reverse peak voltage without a permanent change in diode characteristics.
4. The maximum current unbalance between parallel strings in each phase and between phases shall not exceed plus or minus ten percent for all loading conditions with one string of diodes per phase leg out of service.
5. Parallel diode strings shall be derated so that the most heavily loaded string will not be overloaded. Current balancing shall be achieved with a random selection of diodes.
6. Diodes shall have uniform voltage division within plus or minus ten percent across each diode.
7. Each parallel diode string shall be protected by a current-limiting fuse equipped with an indicator. The fuses shall be sized to withstand any external dc fault or loading condition. The fuses shall blow to clear any failure permitting reverse conduction. A blown fuse indicator shall be visible from outside the rectifier enclosure. Alternative to fuses shall require District approval.
8. The number of diodes per leg shall not exceed 10 for 3-MW and 4-MW units, and 12 for 5-MW units, unless otherwise approved by the District.

D. Terminations

1. The rectifier shall be connected to its associated rectifier transformer through a metal-enclosed busway, as indicated.
2. The rectifier dc output shall be connected either through a metal-enclosed positive bus or cables to its associated 1000 V dc switchgear.
3. The throat connections between equipment and busways shall be designed for close coupling and for installation and removal without the necessity of moving the transformer, rectifier, or dc switchgear.
4. Flanges shall be provided with gaskets to prevent entrance of moisture.
5. The negative dc terminal of each rectifier section shall be bus-connected to the negative disconnect switch through a metering shunt.

E. Negative Disconnect Switch

1. A negative disconnecting switch shall be
 - a. no-load, single-pole, single-throw, non-ferrous, non-magnetic, manually operated, bolted-pressure type, rated for 1500 V dc, 6000A;

- b. provided with one normally-open and one normally-closed auxiliary contact;
 - c. designed with ample space and contact surface for pulling and terminating the negative cables from the negative bus enclosure; and
 - d. key-interlocked with the associated door of the main dc feeder breaker as shown.
- 2. NEMA 2-hole, 750 kcmil standard connectors shall be furnished for the cable terminations as indicated.
 - 3. A viewing window shall permit inspection of the disconnect switch position without opening the rectifier compartment.

F. Relaying, Metering and Indicating Devices

- 1. Relaying, metering, and indicating devices shall be provided as indicated.
- 2. Devices (126DT) shall be installed to detect an abnormal rise in diode heat sink temperatures. Each device shall have at least two stages. First stage contact shall be for annunciation and the second stage for breaker tripping. The pickup point of each stage shall be adjustable and factory-set so that upon the heat sink temperature reaching the preset level the corresponding contact shall initiate an alarm or trip the station circuit breakers through the lockout relay as indicated on the Contract Drawings.
- 3. Devices (180DM) shall be furnished to detect the loss of one or more diode strings.
 - a. Failure of any diode in any string shall initiate an alarm.
 - b. Failure of a second diode shall initiate the tripping of the station circuit breakers via lockout relay (286).
- 4. Rectifier doors to normally energized buses or components and to the negative disconnect switch shall be electrically interlocked to trip the ac and dc main circuit breakers through the lockout relay (Device 286), when a door is opened.

PART 3 – EXECUTION

3.01 TESTING

- A. General: Testing shall be performed in accordance with the requirements specified in Section 01 45 24 - Testing Program Requirements.
- B. Factory Tests
 - 1. Transformer-Rectifier Units: The following design tests shall be performed on one transformer/rectifier unit complete with the 34.5 kV ac circuit breaker, the bus connecting the rectifier transformer to the rectifier, and the accessories. Unless specified otherwise the tests shall be performed with all equipment fully assembled including the enclosures.

- a. Basic Performance Parameters. Design tests shall be performed to verify the efficiency, voltage regulation, displacement power factor, and diode current balance at loads of 0, 25, 50, 75, 100, 150, 300 and 450 percent of rated load.
- b. Temperature Rise Test
 - 1) Contractor shall locate the temperature probes in accordance with the industry standards, and use the test results from the individual probes to calculate the expected temperature rise on all components of the involved equipment, and to verify that local temperatures of the transformer, the rectifier and busway are within the limits indicated in ANSI C34.2, ANSI C37.20.1, ANSI C37.20.2, ANSI C57.18, and NEMA RI-9.
 - 2) The transformer/rectifier units shall be operated at 100 percent full-load till all parts have reached constant temperature before applying overloads. Constant temperature is deemed to be reached if the temperature rise change of any part becomes less than one degree Celsius per hour.
 - 3) After constant temperature has been reached, the transformer/rectifier unit shall be operated at 150 percent full load for two hours with five cycles of 300 percent full load for one minute duration, each equally spaced throughout the two-hour period, followed by one period of 450 percent full load for 15 seconds at the end of the two-hour period.
 - 4) The temperature rise tests may be performed with shorted rectifier output terminals, and at reduced ac input voltage sufficient to produce the required load currents.
- c. Short-Circuit Test
 - 1) Bolted short-circuit fault shall be made on the output terminals of the rectifier to verify the capability of the equipment to withstand the maximum fault current without damage. The source shall be 3-phase, 34.5 kV ac, with fault level of no less than 500 MVA.
 - 2) The fault shall be cleared by the ac circuit breaker's 251B backup overcurrent relay, set the same as it will be on the installed system.
 - 3) Each phase of the ac circuit breaker and the output of the rectifier shall be monitored. Test results of voltages and currents as a function of time shall be recorded on an oscillograph.
- d. Noise Level Tests
 - 1) Noise level tests shall be performed on one transformer/ rectifier unit including the interphase transformer mounted in its permanent location.
 - 2) The noise level at full load, measured in accordance with NEMA TR1 and ANSI C57.12.91, shall not exceed the specified levels.

2. Rectifier Transformers

- a. The following design tests listed in ANSI C57.12.91, C57.18 and NEMA TR1 shall be performed on one rectifier transformer of each size:
 - 1) Dielectric tests - impulse tests. Tests shall include one application of a reduced full-wave, two applications of a chopped wave, followed by one application of a full-wave. These tests shall be performed after the short-circuit tests and temperature rise tests on the rectifier transformer.
 - 2) Audible noise test as in NEMA TR1 and ANSI C57.12.91
 - 3) Impedance and load loss at rated current on the rated voltage connections and on all taps.
 - 4) Commutating reactance and resistance.
 - 5) Short-circuit tests, as described in ANSI C57.12.91, shall be made to evaluate fully the capability of all windings. At least one extreme of the tap range shall be used in the tests. Short-circuits shall be applied on the secondary terminals of each winding.
- b. The following production tests shall be performed on all rectifier transformers in accordance with ANSI C57.18 and NEMA RI-9:
 - 1) Resistance and impedance measurements including zero sequence impedance of all windings on the rated voltage connection of each unit and at all taps.
 - 2) Ratio tests at the rated voltage on all tap connections.
 - 3) Phase-rotation tests on the rated voltage connection.
 - 4) Excitation loss at rated voltage on the rated voltage connection.
 - 5) Excitation current at rated voltage on the rated voltage connection.
 - 6) Dielectric tests - low frequency.
 - 7) Load losses at rated current on the rated voltage connections and on all taps.
 - 8) Partial-discharge tests as follows:
 - a) Raise the applied voltage from 0 to 1.7 p.u within 5 minutes.
 - b) Measure and record the partial discharge levels in increments of 0.2 p.u. voltage above 1.1 p.u.
 - c) Raise the voltage to 2.0 p.u. and hold for 7200 cycles; measure and record the partial discharge every 1800 cycle interval. Record the maximum partial discharge level during the 7200 cycle period.

- d) Lower the voltage to 1.5 p.u. and hold for a 1 hour period. Measure and record the partial discharge levels every 10 minutes.
- e) Partial-discharge shall be less than 100 pico-coulombs at the end of the 1 hour period.

3. Rectifiers

- a. Design tests shall be performed on one rectifier, including the diode protection, monitoring and alarm functions, in accordance with NEMA RI-9 and ANSI C34.2. Design tests shall also be performed on the negative disconnect switch in accordance with ANSI C37.45.
- b. Diode types for use in the rectifier shall be fully tested in accordance with EIA RS-282. Results of these tests, including both routine and type tests shall be submitted to the District.
 - 1) Included in these reports shall be two copies of the Registration Format outlined in EIA RS-282.
 - 2) The test results shall be certified by both the diode manufacturer and the rectifier manufacturer.
- c. End points for all tests shall be well beyond any maximum values to be expected under any loading conditions. Diodes shall be dated as specified using the four-digit code and shall meet or exceed Class B requirements in accordance with EIA RS-282.
- d. Rectifier-type instruments shall not be used in making any of the specified tests. In general, limiting or end point values for reverse current or forward voltage drop shall be at least twice the maximum rated values listed in the registration format. Each curve shall be clearly labeled to show test conditions and shall show actual data points.
- e. The following production tests indicated in NEMA RI-9 and ANSI C34.2 shall be performed on all rectifier units:
 - 1) Dielectric strength test.
 - 2) Rated voltage test.
 - 3) Rated current test. Current imbalance shall be measured:
 - a) between phases
 - b) between each diode in each phase and each phase
 - c) between each diode in each phase and each bank in each phase
 - 4) Diode protective, monitoring and alarm functions.

- f. All applicable tests identified as Production Tests in ANSI C37.41 for the negative disconnect switch.

PART 3 – EXECUTION

Not Used

END OF SECTION 34 21 21